(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 164 685 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
19.12.2001 Bulletin 2001/51

(51) Int Cl.7: H02K 3/28

(21) Application number: 00308848.1

(22) Date of filing: 06.10.2000

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 14.06.2000 US 594357

(71) Applicant: Black & Decker Inc.
Newark Delaware 19711 (US)

(72) Inventor: Wang, Ren Hong
Timonium, Maryland 21093 (US)

(74) Representative: Dlugosz, Anthony Charles et al
Black & Decker Europe European Group
Headquarters 210 Bath Road
Slough, Berkshire SL1 3YD (GB)

(54) Motor armature having distributed windings for reducing arcing

(57) An armature for a brush commutated electric motor having a distributed coil winding arrangement for reducing brush arcing and electro-magnetic interference (EMI). The winding pattern involves segmenting each coil into first and second subcoil portions with differing pluralities of turns. Each subcoil portion is wound around separate pairs of spaced apart slots of a lamination stack. Adjacent coils are wound such that one subcoil portion of each is wound in a common slot to therefore form an overlapping arrangement of each pair of adjacently coils. The winding pattern serves to "shift" the resultant magnetic axes of each coil in such a manner so as to significantly reduce brush arcing and the EMI resulting therefrom. The reduction in EMI is sufficient to eliminate the need for EMI reducing components, such as chokes, which have typically been required to maintain EMI to acceptably low levels. Commutation efficiency is also improved by the distributed winding pattern described above because of the reduction in the unevenness of the magnetic coupling between adjacent coils.

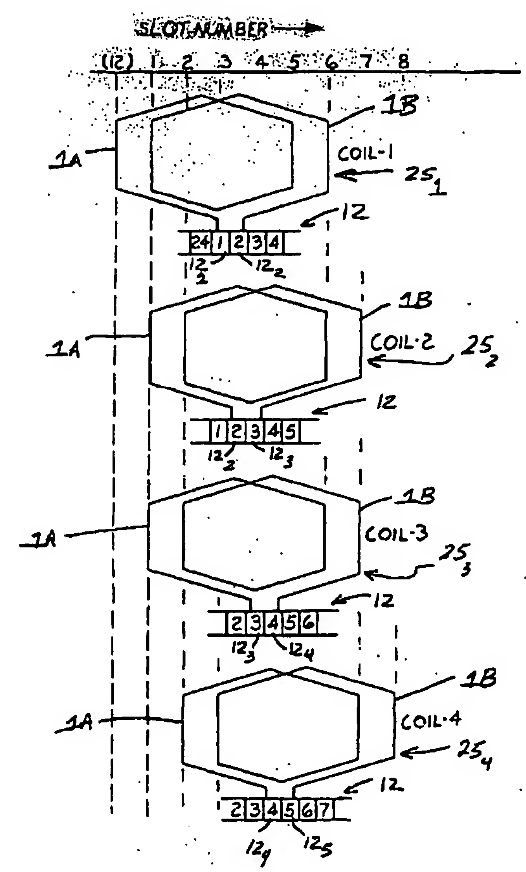


FIGURE 4

EP 1 164 685 A2

Description

[0001] This invention relates to electric motors, and more particularly to a winding pattern for winding the coils on an armature in a manner to reduce electromagnetic interference and arcing at the brushes in contact with the commutator of the armature.

[0002] Present day brush commutated electric motors include an armature having a plurality of coils wound in slots formed in the lamination stack of the armature. With traditional motor designs, the lamination stack of the armature forms a plurality of circumferentially arranged slots extending between adjacent pairs of lamination posts. Typically, two coils per slot are used when winding the armature coils on the lamination stack. Among the two coils of the same slot, the one which commutates first is referred to as the first coil and the one which commutates second as the second coil. The second coil has inherently poorer magnetic commutation than the first coil because the second coil passes beyond the magnetic neutral zone within the stator before it finishes commutation. This is illustrated in simplified fashion in Figure 1, wherein the commutation zone of the first coil is designated by Z_1 and the commutator zone of the second coil is designated by Z_2. A Rotor "R" is shown positioned at the mid-point of the first coil commutation zone. As a result, the second coil commutation can generate significant brush arcing, and becomes the dominant source of the total brush arcing of the motor. This can also cause electro-magnetic interference (EMI) to be generated which exceeds acceptable levels set by various government regulatory agencies. This brush arcing can also lead to accelerated brush wear.

[0003] Accordingly, it is a principal object of the present invention to provide an armature for a brush commutated electric motor having a plurality of coils wound thereon in a unique sequence which serves to significantly reduce brush arcing and improve the commutation efficiency of the motor.

[0004] It is a further object of the present invention to provide an armature for a brush commutated electric motor which incorporates a unique winding pattern for the coils wound on the armature in a manner which does not otherwise require modification of any component of the armature or the need for additional components.

[0005] It is still a further object of the present invention to provide a winding pattern for the armature coils of an armature which allows EMI components usually required to sufficiently attenuate the EMI generated by brush arcing to be eliminated, thus allowing the motor to be constructed less expensively and with fewer components.

[0006] The above and other objects are provided by an armature for a brush commutated electric motor incorporating a unique, distributed winding pattern for the coils thereof, in accordance with a preferred embodiment of the present invention. The winding pattern involves segmenting each coil into first and second subcoil portions. With a first coil, the first subcoil portion is wound around two spaced apart slots for a first plurality of turns and the second subcoil portion is wound around a second pair of spaced apart slots which are shifted circumferentially from the first pair of slots. The second subcoil portion is also formed by a different plurality of winding turns than the first subcoil portion. The two subcoil portions are wound in series with one end coupled to a first commutator segment of the armature and the other end coupled to a second commutator segment.

[0007] A second coil is also divided into first and second subcoil portions, with the first subcoil portion being wound with the same number of turns as the second subcoil portion of the first coil, and in the second pair of spaced apart slots. The second subcoil portion of the second coil, however, is laterally shifted such that it is wound in a third pair of spaced apart slots shifted laterally by one slot from the second pair of slots. The second subcoil portion of the second coil is also wound a plurality of tums in accordance with that of the first portion of the first coil. One end of the first subcoil portion of the second coil is coupled to commutator segment number two while the end of subcoil portion two of coil two is coupled to commutator segment number three.

[0008] Coil number three is segmented into first and second subcoil portions with the first subcoil portion being wound a number of turns in accordance with the second subcoil portion of the second coil, and wound around the second pair of spaced apart slots. The second subcoil portion of the third coil is wound around the third pair of spaced apart slots but with a number of turns in accordance with the first subcoil portion of the second coil. The end of the first subcoil portion of the third coil is coupled to commutator segment number three while the end of the second subcoil portion of coil three is coupled to commutator segment number four.

[0009] The above winding pattern continues in alternating fashion such that an overlapping of the coils occurs around the lamination stack. In effect, all of the first subcoil portions shift their magnetic axes forward with respect to rotation of the armature, and all of the second coil portions shift their magnetic axes backward relative to the direction of armature rotation. With a desired turns ratio between the two subcoil portions of each coil, which ratio may vary considerably but is preferably about 3:1, the above described winding pattern smoothes out the "unevenness" in the magnetic coupling between adjacent armature coils, thus improving commutation efficiency. This also improves the commutation efficiency for the second subcoil portion of each coil, thus reducing brush arcing. This in turn serves to significantly reduce EMI. The reduction of EMI eliminates the need for expensive EMI suppression components that have previously been required for use with the motor brushes to ensure that EMI levels remain below regulated limits.

[0010] The various advantages of the present invention will become apparent to one skilled in the art by

reading the following specification and subjoined claims and by referencing the following drawings in which:

Figure 1 is a simplified diagrammatic end view of an armature having a traditional coil winding pattern employed, and illustrating how the commutation zone of the second coil of a two-coil-per-slot winding arrangement causes the commutation zone of the second coil to lag behind the commutation zone of the first coil, thus leading to brush arcing;

Figure 2 is a side elevational view of an exemplary armature constructed in accordance with the teachings of the present invention;

Figure 3 is a simplified cross sectional end view of the armature of Figure 2 illustrating a lamination stack for an armature having a plurality of twelve slots around which the coils of the armature are to be wound;

Figure 4 illustrates in simplified fashion a coil winding pattern in accordance with the present invention; and

Figure 5 is a simplified end view of the armature illustrating how the winding pattern produces commutation zones for the first and second coil with subcoil portions which are radially aligned with one another to improve commutation efficiency and reduce brush arcing.

[0011] Referring to Figure 2, there is shown an armature 10 for a brush commutated electric motor 11 having a plurality of coils wound in accordance with the teachings of the present invention. The armature 10 includes a commutator 12 which, merely by way of example, includes 24 independent commutator segments 12_1 - 12_{24}. A lamination stack 14 is used to support a plurality of 24 coils 25_1 - 25_{24} wound thereon. An armature shaft 22 extends through the lamination stack 14 and is fixedly coupled to a gear reduction assembly 20 and also to a fan 18. It will be appreciated, though, that the fan 18 and the gear reduction assembly 20 are optional and not essential to the armature 10 of the present invention, and shown merely because they are components that are often used in connection with an armature for an electric motor.

[0012] Referring to Figure 3, the lamination stack 14 is illustrated without any coils wound thereon. The lamination stack 14 includes a plurality of radially projecting lamination posts or "teeth" 24. Twelve slots S_1 - S_{12} are formed between the posts 24. It will be appreciated immediately, however, that while twelve such slots are illustrated, that a greater or lesser plurality could be employed. The overall number of slots depends on the number of commutator segments and will always be one-half the number of commutator segments used.

[0013] Referring now to Figure 4, the winding pattern of the present invention will be described. Coil number 1 (25_1) has a first subcoil portion 1A and a second subcoil portion 1B formed in series with subcoil portion 1A. Subcoil portion 1A has one end thereof coupled to commutator segment number 12_1 and the end of second subcoil portion 1B is coupled to commutator segment number 12_2. Subcoil portion 1A of coil 25_1 includes a first plurality of turns, for example seven turns, which are wound around slots S_{12} and S_5 of the lamination stack 14. Subcoil portion 1B of coil 25_1 is then wound for a larger plurality of turns, in this example 17 turns, in slots S_1 and S_6 of the lamination stack 14. It will be appreciated that the precise number of windings of each subcoil portion can vary considerably, but in the preferred embodiment the number of turns between the subcoil portion 1B and portion 1A of coil 25_1 is such that one has preferably about three times as many winding turns as the other. The number of turns also alternates between the subcoils, as will be described further, such that adjacent coils will always have the two first subcoil portions with differing numbers of winding turns, and the two second subcoil portions with differing numbers of winding turns.

[0014] Coil number 2 (25_2) also has a first subcoil portion 2A and a second subcoil 2B in series with one another. Subcoil portion 2A is wound in slots S_1 and S_6 with seventeen turns. Subcoil portion 2B is wound in series with portion 2A but around slots 5_2 and 5_7 of the lamination stack 14, and with seven winding turns. The end of subcoil portion 2A is coupled to commutator segment 12_2 while the end of subcoil portion 2B is coupled to commutator segment 12_3. The first subcoil portion 2A of coil 25_2 overlaps the second subcoil portion 1B of coil 25_1.

[0015] Coil number 3 (25_3) includes a first subcoil portion 3A and a second subcoil portion in series with one another 3B. Subcoil portion 3A is attached to commutator segment number 12_3 and includes seven winding turns wound around slots S_1 and S_6. Subcoil portion 3B is formed in series with subcoil portion 3A and includes seventeen turns wound in slots S_2 and S_7, with the end thereof being coupled to commutator segment 12_4.

[0016] Coil 4 (25_4) also includes a first subcoil portion 4A and a second subcoil portion 4B in series with subcoil portion 4A. Subcoil portion 4A has its end coupled to commutator segment 12_4 and includes seventeen turns wound around slots S_2 and S_7. Subcoil portion 4B includes seven turns wound around slots S_3 and S_8, with the end thereof being coupled to commutator segment 12_5. It will be noted that coil 25_4 partially overlaps coil 25_3. In effect, one of the subcoil portions of each adjacent pair of coils 25 overlap with each other.

[0017] The above-described pattern for coils 25_1 - 25_4 is repeated until all of the coils (in this example 12 coils) are wound onto the lamination stack 14. Each of the ends of the coils 25_1 - 25_{12} are further secured to immediately adjacent pairs of commutator segments 12_1 - 12_{24}. For example, coil 25_5 has its ends secured to commutator segments 12_5 and 12_6, coil 25_6 to segments 12_6 and 12_7, and so forth.

[0018] The above-described winding pattern signifi-

cantly improves the commutation performance of all of the second coil portions of the coils 25. Splitting each coil 25 into first and second subcoil portions allows each first subcoil portion to shift its magnetic axis away (i.e., laterally), from the position it would have otherwise had in a traditional two-coil-per-slot approach. This is illustrated in Figure 5. All of the first subcoil portions shift their magnetic axes forward to produce a first coil commutation zone, as indicated by line 30, and all of the second subcoil portions shift their magnetic axes backward to produce a second coil commutation zone, as indicated by line 32, in reference to the armature's 10 rotational direction. Both of these commutation zones are now in a magnetic neutral zone between field coils 34. With a turns ratio between the two subcoils of about 3:1, this winding pattern smoothes out the magnetic "unevenness" between adjacent coils, which is a drawback with traditional two-coil-per-slot winding patterns. This, in connection with the shifting of the resultant magnetic axes of each coil, serves to significantly improve the commutation efficiency of the motor and to reduce the overall brush arcing.

[0019] The winding pattern employed on the armature 10 of the present invention also serves to significantly reduce the cost of constructing the armature by eliminating components that would otherwise be needed to sufficiently attenuate the EMI that results from traditional two-coil-per-slot winding patterns. Typically, inductive components are required to form a choke circuit associated with each armature brush. These additional components increase the overall cost of manufacturing a motor, as well as increase the complexity of the task of replacing the brushes during repair procedures.

[0020] The apparatus and method of the present invention thus allows an armature to be formed which significantly reduces brush arcing, and therefore the EMI that is present with traditional two-coil-per-slot armature constructions for all brush commutated electric motors. The apparatus and method of the present invention further does not increase the complexity of the manufacturing process or require additional component parts that would otherwise increase the overall cost of construction of an armature.

[0021] Those skilled in the art can now appreciate from the foregoing description that the broad teachings of the present invention can be implemented in a variety of forms. Therefore, while this invention has been described in connection with particular examples thereof, the true scope of the invention should not be so limited since other modifications will become apparent to the skilled practitioner upon a study of the drawings, specification and following claims.

Claims

1. An electric motor having an armature with a coil winding pattern for reducing brush arcing and electromagnetic interference, comprising:

   a lamination stack having a plurality of radially extending posts, said posts forming a plurality of slots therebetween, said slots being arranged in a circumferential pattern;
   a plurality of coils wound around said slots, with each said coil being divided into first and second subcoil portions, with said first subcoil portion having a first plurality of winding turns and said second subcoil portion having a second plurality of winding turns, and wherein said first and second subcoil portions are wound in different, circumferentially offset pairs of said slots and coupled to first and second commutator segments of a commutator; and
   wherein said coils are wound such that adjacent pairs of said coils are wound in an overlapping fashion, with the second subcoil portion of a first coil of each said coil pair wound in the same pair of said slots as the first subcoil portion of a second coil of each said coil pair.

2. The electric motor of claim 1, wherein one of said first and second subcoil portions of each coil has approximately three times the winding turns of the other.

3. The electric motor of claim 2, wherein said second subcoil portion is wound around a pair of said slots which are shifted circumferentially by one said slot position from the second subcoil portion of its adjacent said coil.

4. The electric motor of claim 1, wherein ends of said first and second subcoil portions are coupled to said commutator segments such that an end of each said second subcoil portion of each said coil is coupled to the same said commutator segment as the first subcoil portion of its adjacent said coil.

5. A method for winding an armature of an electric motor, wherein the armature has a lamination stack forming a plurality of circumferentially arranged slots for winding thereon a plurality of coils, said method comprising:

   segmenting a first coil into first and second subcoil portions in series with one another;
   winding said first subcoil portion of said first coil around a first pair of spaced apart ones of said slots with a first plurality of winding turns;
   winding said second subcoil portion of said first coil around a second pair of spaced apart slots, which are circumferentially shifted from said first pair of slots, with a second plurality of winding turns;
   segmenting a second coil into first and second

subcoil portions in series with one another;
winding said first subcoil portion of said second coil around said second pair of spaced apart ones of said slots a number of turns in accordance with a third plurality of winding turns; and
winding said second subcoil portion of said second coil around a third pair of spaced apart slots shifted circumferentially from said second pair of spaced apart ones of said slots, with a fourth plurality of turns.

6. The method of claim 5, wherein said second and third pluralities of winding turns are equal to one another.

7. The method of claim 5, wherein said first and fourth pluralities of winding turns are equal to one another.

8. The method of claim 5, wherein said first and second pluralities of winding turns differ such that one is always about three times the number of the other.

9. The method of claim 5, further comprising the steps of:

segmenting a third coil into first and second subcoil portions in series with one another;
winding said first subcoil portion of said third coil around said second pair of spaced apart ones of said slots a number of turns in accordance with said first plurality of winding turns; and
winding said second subcoil portion of said third coil around said third pair of spaced apart ones of said slots a number of turns in accordance with said second plurality of winding turns.

10. The method of claim 9, further comprising the steps of:

segmenting a fourth coil into first and second subcoil portions in series with one another;
winding said first subcoil portion of said fourth coil around said third pair of spaced apart slots with a number of turns in accordance with said second plurality of winding turns; and
winding said second subcoil portion of said fourth coil around a fourth pair of spaced apart ones of said slots shifted circumferentially by one slot position from said third pair of spaced apart ones of said slots, with a number of winding turns in accordance with said first plurality of winding turns.

11. A method for winding an armature of an electric motor, wherein the armature has a lamination stack forming a plurality of circumferentially arranged slots for winding thereon a plurality of coils, said method comprising:

segmenting a first coil into first and second subcoil portions in series with one another;
winding said first subcoil portion of said first coil around a first pair of spaced apart ones of said slots with a first plurality of winding turns;
winding said second subcoil portion of said first coil around a second pair of spaced apart slots which are circumferentially shifted from said first pair of slots, with a second plurality of winding turns;
segmenting a second coil into first and second subcoil portions in series with one another;
winding said first subcoil portion of said second coil around said second pair of spaced apart ones of said slots a number of turns in accordance with said second plurality of winding turns;
winding said second subcoil portion of said second coil around a third pair of spaced apart slots shifted circumferentially from said second pair of spaced apart ones of said slots, with a number of turns in accordance with said first plurality of winding turns;
segmenting a third coil into first and second subcoil portions in series with one another;
winding said first subcoil portion of said third coil around said second pair of spaced apart ones of said slots a number of turns in accordance with said first plurality of winding turns;
winding said second subcoil portion of said third coil around said third pair of spaced apart ones of said slots a number of turns in accordance with said second plurality of winding turns;
segmenting a fourth coil into first and second subcoil portions in series with one another;
winding said first subcoil portion of said fourth coil around said third pair of spaced apart slots with a number of turns in accordance with said second plurality of winding turns; and
winding said second subcoil portion of said fourth coil around a fourth pair of spaced apart ones of said slots shifted circumferentially by one slot position from said third pair of spaced apart ones of said slots, with a number of winding turns in accordance with said first plurality of winding turns.

12. The method of claim 11, further comprising the steps of:

securing ends of said first coil to adjacent first and second commutator segments of a commutator; and
securing a first end of said second coil to said second commutator segment and a second end of said second coil to a third commutator segment of said commutator, with the third

commutator segment being disposed immediately adjacent said second commutator segment.

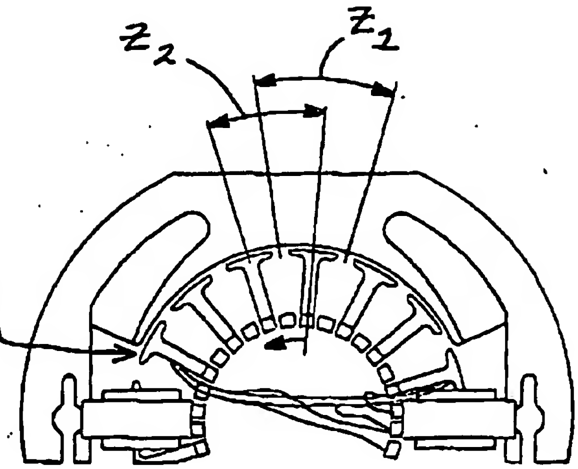
13. The method of claim 12, further comprising the steps of:

securing a first end of said third coil to said third commutator segment and a second end of said third coil to a fourth commutator segment, the fourth commutator segment being disposed immediately adjacent said third commutator segment.

14. The method of claim 13, further comprising the steps of:

securing a first end of said fourth coil to said fourth commutator segment and securing a second end of said fourth coil to a fifth commutator segment disposed immediately adjacent said fourth commutator segment.

15. The method of claim 11, further comprising the step of selecting said first and second pluralities of winding turns such that one includes approximately three times the turns of the other.



PRIOR ART

FIGURE 1

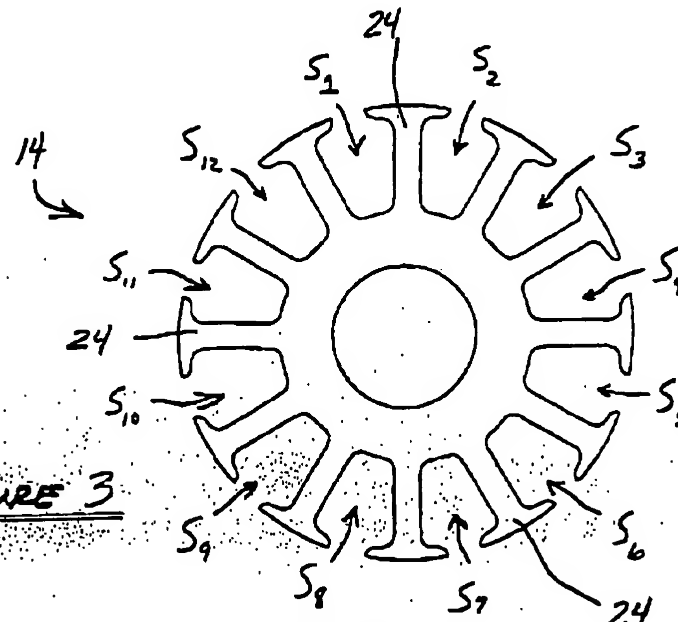


FIGURE 3

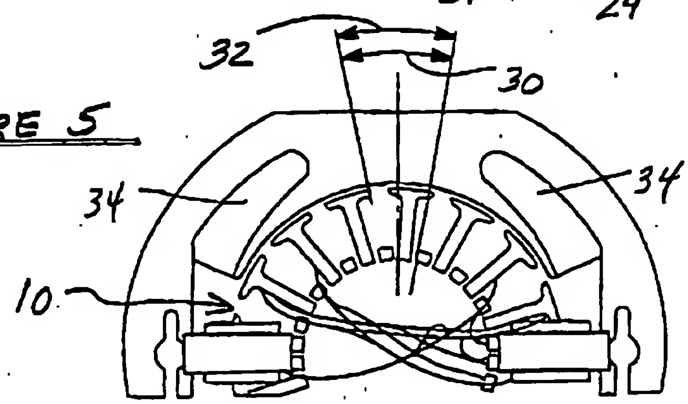


FIGURE 5

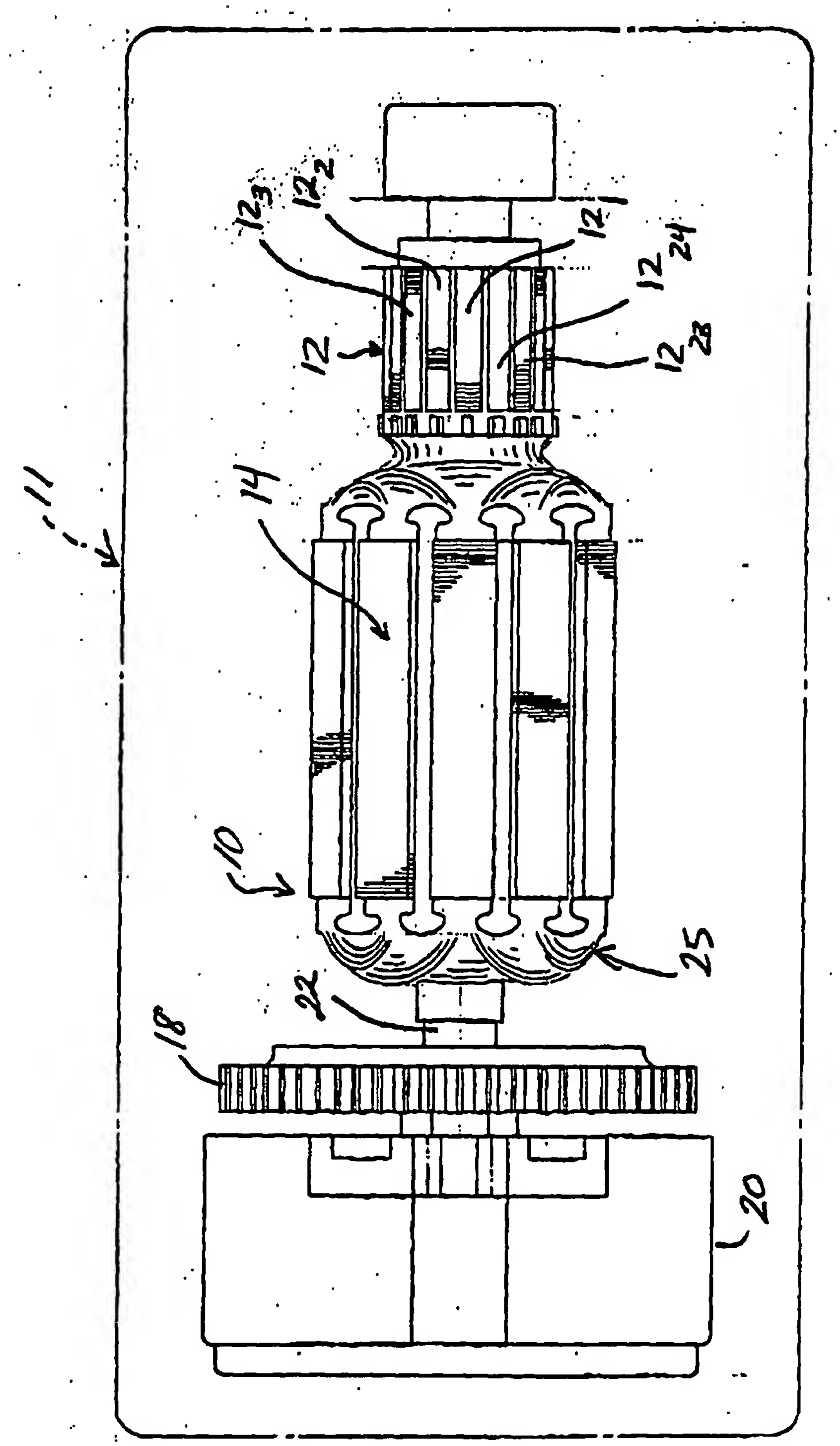


FIGURE 2

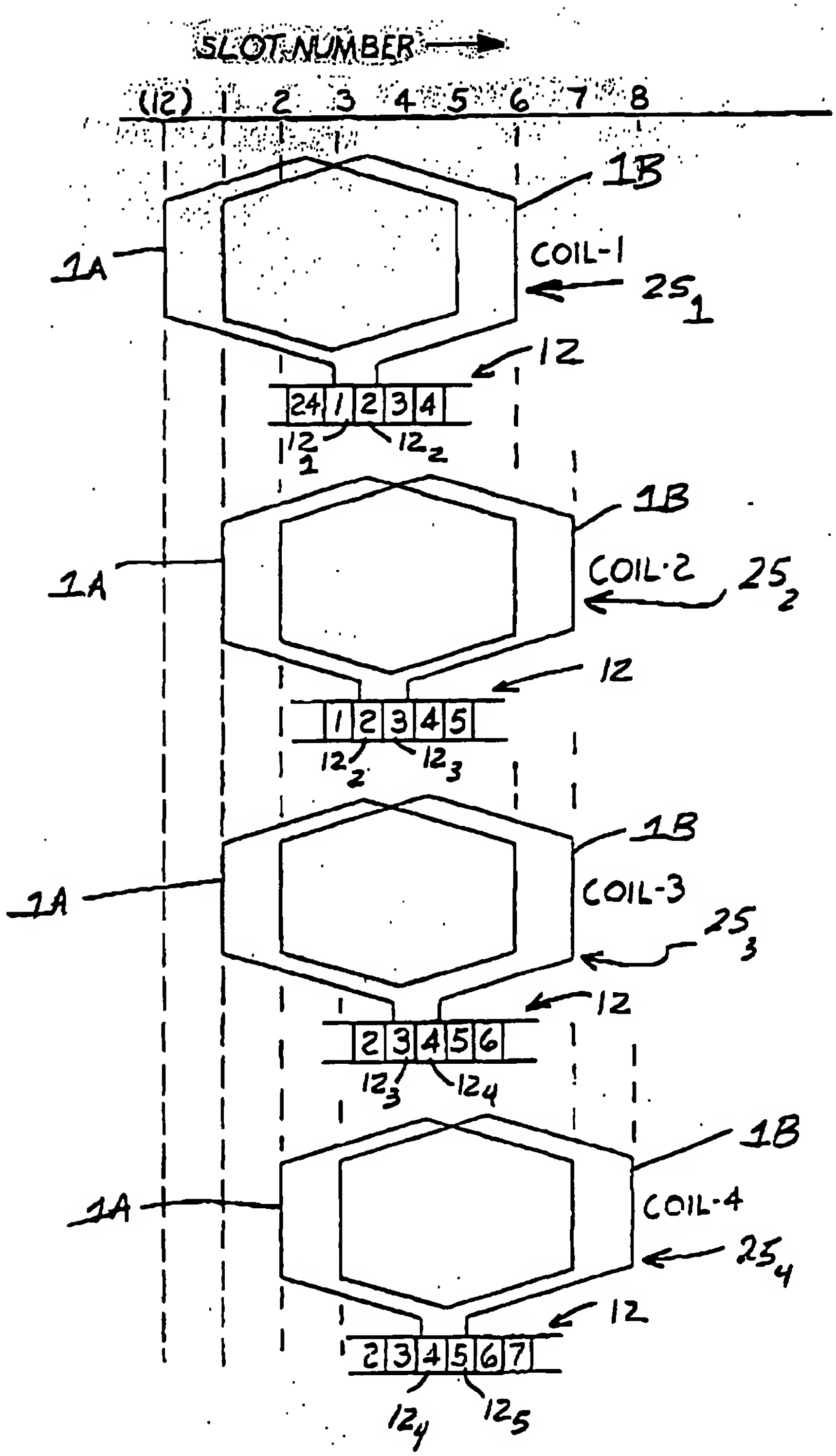

SLOT NUMBER
(12) 1 2 3 4 5 6 7 8
1B
COIL-1
1A
25_1
12
24 1 2 3 4
12_1
12_2
1B
COIL-2
1A
25_2
12
1 2 3 4 5
12_2
12_3
1B
COIL-3
1A
25_3
12
2 3 4 5 6
12_3
12_4
1B
COIL-4
1A
25_4
12
2 3 4 5 6 7
12_4
12_5

FIGURE 4